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Economic and Sustainable Evaluation of Fertilizer Application scenarios for Iowa Crop/Livestock

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Economic and Sustainable Evaluation of Fertilizer Application scenarios for Iowa Crop/Livestock Operations

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INTRODUCTION

Increased awareness and concern for environmental quality in recent years has increased pressure on farmers to develop and utilize methods to minimize the environmental impact of their production activities. The use of manure produced by livestock enterprises to meet crop nutrient needs is one method that has been used to reach these sustainable environmental goals. The purpose of this study is to evaluate the economic impact on returns of using swine manure to meet crop nutrient needs on a typical midwest crop/livestock farm.

An important concern of farmers in a crop/livestock operation such as the one in this study is the lack of sufficient time to apply the manure during labor intensive periods in the crop enterprises. Availability of nutrients in the manure is highest when it is applied in the spring. This is the time when crops also require labor for planting operations. This research evaluates the economic trade-offs of hiring labor to meet labor needs of all the enterprises during these periods, minimize costs and provide a foundation for a sustainable production system.

Enterprise budgets are combined into a linear programming framework to evaluate the farm level impacts of sustainable production alternatives. Linear programming can be used effectively and efficiently to evaluate alternative case studies like those presented in this work.

This study simulates a typical Iowa crop/livestock farm using economic engineering analysis. The crop enterprise choices compare a corn-soybean rotation to continuous corn. The swine enterprise is constrained to a maximum of 90 sows, farrowing twice a year. Various alternatives for fertilizer application are compared. They include commercial fertilizer application or manure application via a liquid spreader, stationary spray gun or delivery cord.[2] Estimation of costs, returns, and labor requirements are taken from Iowa State Extension budgets and existing research.

[2] delivery cord is a method in which field injection equipment is attached to a continous line directly to the manure storage system.

The farm has 400 tillable acres with a farrow to finish total confinement hog facility. The hog facility has the capacity of 180 litters of hogs per year. Farm implements available, sizes, field capacities and labor requirements used are standard for an Iowa swine/corn operation as suggested by the Iowa extension enterprise budgets.

This paper is divided into three main sections. In the first part, each enterprise system is described and assumptions outlined. The second section summarizes the results of the optimization of various scenarios described in the first section. The final part summarizes the important results and draws appropriate conclusions.

The Labor System

Labor availability is one full-time individual. The calendar year has been divided into 16 time periods. In addition to the intra-period constraints on operator labor, the operator is restricted to 3000 total hours of labor per calendar year. A labor hiring activity is included at $5.00 per hour in the model to allow for part-time help during times of labor competition between the crop and hog enterprises. The distribution of labor requirements per day required under the various scenarios of this model is included in the results section of this paper. After first optimizing each scenario, which are discussed later in this paper, hired labor is then restricted to zero and the model rerun to determine the potential value of hired labor by comparison of objective function results and shadow price analysis.

Labor which could be used in the cropping system is constrained by the weather. The average time period which would allow for crop production activities is defined as "days available for fieldwork." For the purposes of this study, days available for fieldwork are the average days available over the period 1957 to 1988.[3]

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[3]. "Fieldwork Days Available in Iowa" Mike Duffy. Staff working paper. Department of Economics, Iowa State University, 1989.

The Cropping System

All 400 acres of the representative farm are tillable and of good productive capacity. Land needed for livestock enterprises does not compete with that of the cropping system. The specific mix of planting, disking, and other crop operations is typical for a high management/low input system.

Information on expected crop yield related to the level of fertilizer applied is reported in Table 1. Nitrogen is based on pounds of nitrogen applied per acre.

Table 1 Expected Crop Yield and Fertilizer Requirements

Corn Yield	N	P	K
100	120	37.5	30
125	150	46.87	37.5
150	180	56.25	45

Soybean Yield	N	P	K
30	0	24	45
40	0	32	60
50	0	40	75

Source: Animal Manure: A Source of Crop Nutrients, 1985.

The corn price used is $2.34[4] per bushel, the average price for the 1982 through 1988 calendar years. The impact of planting time on corn yields is reported in "Fertilizer Value of Swine Manure." Generally, the later that planting occurs the lower the expected yield. Adjustments in yield potential are made accordingly in this model. Variable cost coefficients are based on information reported in the "Estimated Costs of Crop Production in Iowa-1990." The model must choose the optimal mix of planting times, rotations, and labor demnad given these potential yield trade-offs. Nitrogen from the soybean production will also help reduce nitrogen requirements for the corn the following year.

[4] All prices based on average central Iowa cash prices.

The swine production system

The swine system includes facilities for up to 180 litters of hogs in a total confinement system with 45 litters per farrowing. Farrowings occur four times per year in March, June, September, and December. The required labor is constant during non-farrowing months with increased labor requirements during the farrowing months, as would be expected. Labor required is 12 hours per litter/year.[5]

The majority of the work for the hog operation can be completed regardless of the weather. The model provides labor availability for the hog operation during non-fieldwork days to minimize its conflict with the cropping operations. A minimum amount of work is required, however, each day for maintenance and feeding of the hogs. This time requirement does compete with the crop operations and is a trade-off the model also considers. The work that needs to be done but can wait until the end of the day or until poor weather restricts crop operations, is modeled not to compete with the crop enterprises but to be completed during slack labor times. The coefficients of labor requirements are reported in Table 2.

Table 2 Labor Requirements per Litter by period

Labor period	Total labor Required	Minimum Labor requirement
January	0.93	0.93
February	0.93	0.93
March	1.14	1.14
April (1st half)	0.465	0.1414
April (2nd half)	0.465	0.2288
May (1st half)	0.465	0.2859
May (2nd half)	0.465	0.3092
June (1st half)	0.57	0.3688
June (2nd half)	0.57	0.4223
July (1st half)	0.465	0.3514
July (2nd half)	0.465	0.3985
August	0.93	0.93
September	1.14	1.14
October	0.93	0.6786
November	0.93	0.4683
December	1.14	1.14

[5] "Livestock Enterprise Budgets for Iowa-1990."

The objective function value for the swine enterprise system is derived from the livestock enterprise budgets discussed above. The market hog price is $48.41 per cwt. with an average weight at sale of 235 pounds. The cull sow price is $40.91 with an average weight of 400 pounds. Prices are the calendar year averages for central Iowa cash markets for the years 1982 through 1988[6]. In addition, 7.4 head of market hogs and .38 cull sows are marketed for each litter. This requirement provides modeling typical marketing rates of mature hogs, death loss, and rotation of breeding stock.

A study by Melvin, Sutton and Vanderholm, provides information on the quantity of manure produced by hogs. The study also provides information on fertilizer nutrient composition of the manure, and nitrogen losses to the air as affected by application method and time of the year the manure is applied. The latter will be discussed in greater detail in the manure application section. Nutrients in manure produced per litter of hogs is reported in the Melvin study as 73.75 pounds of nitrogen, 67.5 pounds of phosphorus and 55 pounds of potassium. A litter of pigs and sow will produce 2500 gallons manure. The herd of 180 litters produces about 450,000 gallons of manure per year. This averages 37,500 gallons per month.

The Manure Application System

All manure is applied to meet N,P, and K requirements. Commercial application is used to bring levels of nutrients to satisfactory rates when manure supplies are exhausted or uneconomical. Four separate manure application time alternatives are considered in the model. They are:

1. Spring- Application of all of the manure just prior to planting with immediate incorporation.
2. Spring/Fall- Application of half of the manure just prior to planting in the spring, with the remainder applied after harvest in the fall with immediate incorporation.
3. Fall- All the manure applied after harvest in the fall and immediately incorporated.
4. Winter- All the manure applied during the winter.

[6] Iowa State University Extension Market News Service.

The manure is applied using a 2200 gallon liquid spreader, a stationary spray gun, or delivery cord. Available nitrogen levels (Melvin et. al.) for various application methods and times are presented in Table 3.

Table 3 Manure Available from hog production

Spreader & Delivery Cord	Percent Loss			Pounds Available/litter		
Application Time	N	P	K	N	P	K
Spring	5	30	30	70.06	47.25	38.5
Spring/Fall	7.5	30	30	68.2	47.25	38.5
Fall	10	30	30	66.37	47.25	38.5
Winter	37.5	30	30	46.09	47.25	38.5

Spray Gun	Percent Loss			Pounds Available/litter		
Application Time	N	P	K	N	P	K
Spring	30	30	30	51.62	47.25	38.5
Spring/Fall	32.5	30	30	49.78	47.25	38.5
Fall	35	30	30	47.93	47.25	38.5
Winter	62.5	30	30	27.65	47.25	38.5

Source: Fertilizer Value of Swine Manure

Application of commercial fertilizer is assumed to be the alternative to manure application. Prices for application of commercial nutrients on a per pound basis of N,P, and K are \$.122, \$.203, and \$.1375, respectively. Levels of nutrient application are based on plant removal rates (Kilorn). Application charges are \$5.50 and \$2.60 per acre for anhydrous and bulk respectively.

Comparisons of net returns over variable costs are considered for operations that have the following options for fertilzer application:

1. Commercial application only- no manure application equipment is available.

2. Commercial/liquid spreader- a combination of commercial application and liquid spreader to inject manure.

3. Commercial/spray gun- a combination of commercial application and stationary spray gun to spread manure.

4. Commercial/delivery cord- a combination of commercial application and delivery cord to inject manure.

5. No restrictions- all forms and combinations of application methods are possible.

Application costs for the stationary spray gun and delivery cord are based on 1990 custom prices[7] and are converted to a per pound of nitrogen basis in the model.

The manure storage system

The manure storage system is an above ground steel tank structure. Interest and insurance rates are assumed to be 12.5 percent and .75 percent respectively. Useful life is assumed to be 25 years with a zero salvage value. Estimated storage capacity, initial costs, and yearly costs are based on average expected prices.

The economic optimization model

Linear programming is used for optimization of the model scenarios. The model is specified as follows:

$$\text{Maximize } \sum_{j=1}^{n} c_j x_j \text{ (for all j)}$$

Subject to the constraints:

$$\sum_{i=1}^{m} \sum_{j=1}^{n} a_{ij} x_j \leq b_i$$

$$x_j \geq 0 \text{ (for all j)}$$

Where:

x_j = the possible alternative activities $j=1,...,218$

c_j = net income over variable costs

a_{ij} = the relationship between the ith resource and the jth activity, and

b_i = the ith resource or constraint restriction level $i=1,...,173$.

[7] Northwest Lagoon Pumping service, Marcus, IA.

Objective function results

Four seperate manure application activities each with four possible application time scenarios, and the commercial application only alternatives provide 17 seperate model scenarios. Returns over variable cost, as represented by the objective function values, for each of the 17 scenarios are represented in Table 4. In each case the unrestricted fertilizer application method choice yields the highests returns. In cases where the objective function results between two scenarios are equal, the optimal choice of application method and time of application chosen in the two scenarios are identical. When the model is given the choice of using only commercial fertilizer or delivery cord application, the model chooses to use only commercial application. The delivery cord method is comparatively more expensive and is not chosen. This optimization choice holds regardless of the time of application and, hence, the objective function results for the delivery cord application are constant for each application scenario. The table shows the results for the unrestricted optimized model as well as for the scenarios where hired labor was restricted to zero and for various combinations of application methods.

Table 4 Objective function values for different scenarios tested (in dollars)

Hired Labor available

		Method of Application			
Time of Application	Unrestricted	Liquid Sprdr./ Commercial	Spray Gun/ Commercial	Del. Cord/ Commercial	Commercial Only
Spring	122609.7	122609.7	121790.2	117798	117798
Spring/Fall	122787.9	122787.9	121703	117798	
Fall	122899	122899	121615.76	117798	
Winter	121914.8	121914.8	120679.3	117798	

Objective Function values for scenarios tested
Hired Labor restricted to zero

Time of Application	Unrestricted	Method of Application Liquid Sprdr./ Commercial	Spray Gun/ Commercial	Del. Cord/ Commercial	Commercial Only
Spring	119494.6	116370.8	118874.2	114881.9	117798
Spring/Fall	119655.5	118930.3	118786.9	114881.9	
Fall	119983.6	119983.6	118699.6	114881.9	
Winter	118915.2	118867.8	117763.2	114881.9	

Enterprise mix

The optimum combination of enterprises in each case include the planting of all available acreage in a timely manner and full utilization of the hog facilities. Results include full use of the hog manure in each case that allowed its use. Returns are maximized through consistently taking advantage of all produced hog manure for fertilizer credit regardless of time of manure application or application method. When necessary, labor is hired to perform these activities. The optimal choices when hired labor is restricted to zero consistently yield objective function values below those when hired labor is available. The crop enterprise mix, in acres produced, and commercial nutrient purchase level, in pounds of nitrogen, is shown in Table 5 for each scenario. Each scenario uses 400 acres, 180 litters of hogs and 13,270 pounds of nitrogen from the available hog manure. The only differences in results are the levels of commercial nitrogen applied and hired labor. Variations in the objective function values, therefore, are due largely to variations in the amount of commercial fertilizer that must be purchased with changing application times, manure availability, and availability of hired labor. Levels of N,P, and K per 1000 gallons of hog manure are highly variable from farm to farm. However, a reduction in the parameter values of nutrient contributions from hog manure of 20 percent only reduces net returns by $200 to $400 across all scenarios in the model. All scenarios chose to produce a corn-soybean rotation with yield goals of 150 and 50 bushels respectively.

Table 5 Crop Enterprise Mix and Commercial Fertilizer Purchased

Spring Application of Manure

	Any Method		Sprdr./ Commercial		Sp. Gun/ Commercial		Del. Cord/ Commercial	
Corn Apr. (1)[8]	200[9]	53	200	53	200	53	200	53
Corn Apr. (2)		96.3		96		96		96
Corn May (1)		50.6		50		50		50
Beans Apr. (2)	163	81.6	163	81	163	81	163	81
Beans May (1)	36.9	46.3	36.9	46	36.9	46	36.9	46
Beans Jun. (1)		72.1		72		72		72
Hogs	180	180	180	180	180	180	180	180
Comm. Fert.[10]	21392	21390	21392	38547	24709	24709	45036	45036

Spring/Fall Application of Manure

	Any Method		Sprdr./ Commercial		Sp. Gun/ Commercial		Del. Cord/ Commercial	
Corn Apr. (1)	200	53	200	67	200	53	200	53
Corn Apr. (2)		96.3		63		96		96
Corn May (1)		50.6		70		50		50
Beans Apr. (2)	163	81.6	163	73	163	81	163	81
Beans May (1)	36.9	46.3	36.9	30	36.9	46	36.9	46
Beans Jun. (1)		72.1		96		72		72
Hogs	180	180	180	180	180	180	180	180
Comm. Fert.	21725	21725	21725	24488	25042	25043	45037	45037

Fall Application of Manure

	Any Method		Sprdr./ Commercial		Sp. Gun/ Commercial		Del. Cord/ Commercial	
Corn Apr. (1)	200	53	200	53	200	53	200	53
Corn Apr. (2)		96.3		96		96		96
Corn May (1)		50.6		50		50		50
Beans Apr. (2)	163	81.6	163	81	163	81	163	81
Beans May (1)	36.9	46.3	36.9	46	36.9	46	36.9	46
Beans Jun. (1)		72		72		72		72
Hogs	180	180	180	180	180	180	180	180
Comm. Fert.	22056	22058	22056	22058	25374	25375	45037	45037

[8] The parenthesized number refers to the first or second half of the month.

[9] The first column in each catagory refers to the optimal mix with hired labor, the second with hired labor restricted to zero.

[10] Based on pound of nitrogen purchased commercially, the pounds of P and K purchased are in proportion to N purchased according to plant removal rates.

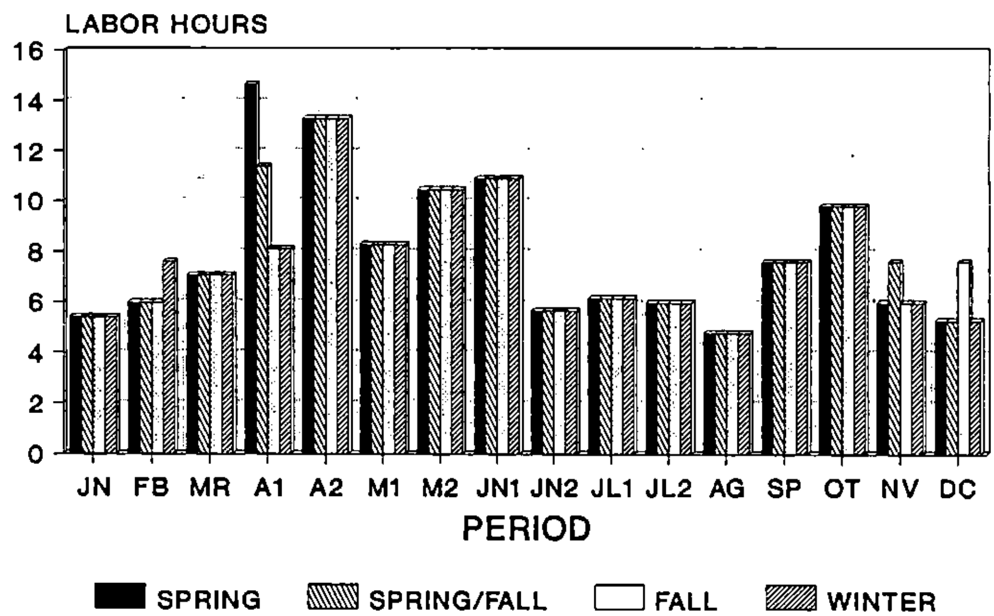
Winter Application of Manure

	Any Method		Sprdr./ Commercial		Sp. Gun/ Commercial		Del. Cord/ Commercial	
Corn Apr. (1)	200	53	200	53	200	53	200	53
Corn Apr. (2)		96.3		96		96		96
Corn May (1)		50.6		50		50		50
Beans Apr. (2)	163	81.6	163	81	163	81	163	81
Beans May (1)	36.9	46.3	36.9	46	36.9	46	36.9	46
Beans Jun. (1)		72		72		72		72
Hogs	180	180	180	180	180	180	180	180
Comm. Fert.	25705	25706	25705	26750	31619	31619	45037	45036

Labor distribution

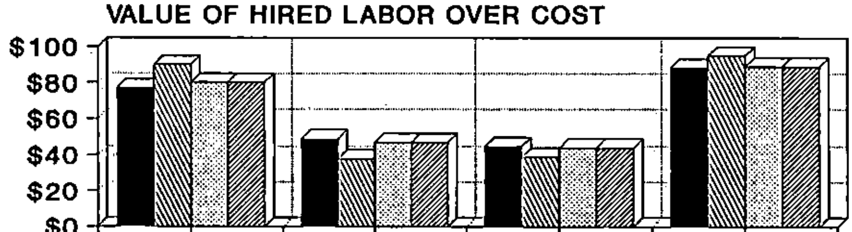
The distribution of total labor requirements per day is shown in Figure 1 for the 16 manure application scenarios tested. In each case the labor requirement per day does not exceed 16 hours. This is a modest requiremnt for a full-time producer with seasonal hired labor. The distributions are distinguished mainly in labor demand variation due to the time of manual manure application selected.

DISTRIBUTION OF TOTAL LABOR/DAY BY PERIOD (FIGURE 1)



NO RESTRICTIONS

VALUE OF HIRED LABOR FOR APPLICATION OF MANURE (FIGURE 2)



	APRIL2	MAY1	MAY2	JUNE1
SPRING APPL.	$76.9	$49	$44.9	$88.1
SPRING/FALL	$90	$38	$39	$95
FALL	$80	$47	$44	$89
WINTER	$80	$47	$44	$89

APPLICATION TIME

SPRING APPL. SPRING/FALL
FALL WINTER

The 16 scenarios were optimized for unrestricted hired labor and with hired labor restricted to zero. The shadow prices of hired labor under these restrictions are shown in Figure 2. Clearly, although maximizing returns requires the use of hired labor. The value of the hired labor to the returns is far greater than its cost. Additionally, full use of manure for nitrogen credits and reduced commerical fertilizer application provides a more environmentally appealing practice.

Summary and Conclusions

Effective use of hog manure in crop production requires increased management. The purpose of this study is to investigate the economic potential for commercial fertilizer application compared to use of on farm produced swine manure for nutrient credit. Under the assumptions of the model, the hiring of labor to apply manure is found be of economic benefit under all scenarios studied. Additionally, returns over variable cost are consistently higher when manure is used optimally compared to only using commercial fertilizer. All crops and hog production can be managed in timely manner by utilizing hired labor. Modest levels of seasonal hired labor will provide adequate total labor supply.

The specific enterprise mix and timeliness of planting are detailed in the results section. Both the mix and planting times concur with what would be expected under similar circumstances in an actual operation.

Specific conclusions are as follows:

1. The use of manure to help meet corn production nitrogen requirements is profitable, but often requires hiring part-time labor for incorporation of manure when nutrient availability is highest. This allows the operator to fully utilize all crop acreage and swine facilities.

2. Total labor demands per day during peak periods do not exceed that which would be considered feasible for a full time operator with additional seasonal help. Peak farm labor requirements per day do not exceed 16 hours.

3. The manure handling system did not affect planting times. Planting times are consistent with that which would be expected for this type of farm. All crops are planted in a timely manner.

4. Farm returns are increased through effecient use of manure from swine operation.

5. Farm returns are increased through hiring labor in a crop rotation system.

6. In addition to environmental impacts, the sole use of commercial fertilizer reduces returns, in all cases, by as much as 5 percent.

7. Variation in the amount of nutrients provided in the manure does not significantly affect the results.

BIBLIOGRAPHY

Alleman Cooperative Retail Price Quote Sheet. Iowa. 1989.

Benson, F.J. and K.E. Gensmer. Minnesota Farm Machinery Economic Cost Estimates for 1986, University of Minnesota, Minneapolis. 1986.

Cooperative Extension Service. Estimated Costs of Crop Production in Iowa-1990. Iowa State University, Ames. 1990.

Cooperative Extension Service. Livestock Enterprise Budgets for Iowa-1990. Iowa State University, Ames. 1990.

Duffy, Mike. ISU Farming Systems Project Observations on 1988 Crop Year. Iowa State University Economics Department. 1989.

Duffy, Mike. Fieldwork Days available in Iowa. Iowa State University Department of Economics Staff Working Paper. 1989.

Killorn, Randy. Animal Manure: A Source of Crop Nutrients. Iowa State University Cooperative Extension Service Bulletin No. Pm-1164. 1985.

Melvin, S. W., A. L. Sutton and D. H. Vanderholm. Fertilizer Value of Swine Manure. Cooperative Extension Service Bulletin No. AS-453. 1984.

Northern Research Center and Clarion-Webster Research Center. Annual Progress Reports. Kanawha, Iowa. 1986.

Voss, R. D., W. D. Shrader. Crop Rotations: Effect on Yields and Responses to Nitrogen. Iowa State University Cooperative Extension Service Bulletin No. Pm-905. 1988.